

Appendix A

Methodology Used to Estimate Drainage DOC and TFPC Releases

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The following explains how the estimates of drainage DOC and TFPC contribution in the simple Delta model were derived. Equations used in the computations are presented in Table 1.

Estimated Island Drainage Volumes

The most complete survey of monthly island drainage flows was made for May 1954 through October 1955 and reported in DWR *Report No. 4: Quantity and Quality of Water Applied To and Drained from the Delta Lowlands* (DWR, 1956). The assumption was made that present-day drainage volume and discharge patterns have not significantly changed in the last 40 years. From May through October, there were two sets of monthly estimates, one set for 1954 and the other for 1955. The average was used when two estimates occurred for the same month to obtain a single set of 12 monthly drainage volume estimates. These values were assumed to be constant during 1987-91.

The 1954-55 survey showed the highest drainage discharges occurred during January and December with the lowest flows in February, March, and April. These estimates would reflect the pattern of rainfall that existed during the 1954-55 survey. During the period of this study, the pattern of rainfall shifted, and calendar year 1988 was the only year in which the higher precipitation rates occurred in January and December. During other years, highest rates of rainfall occurred during February, March, or April. These differences in rainfall patterns point to the need to collect current drainage data.

The first heavy rainfall after a prolonged dry period results in a higher organic load in the streams and Delta channels. However, continued rainfall could have a diluting effect and the water quality could improve. Under these conditions, the timing and frequency of water quality sample collection is critical to understanding the impacts of island drainage.

The Delta islands were divided into two groups for calculating the water quality estimates. These two groups exhibit different water quality characteristics and rates of drainage. One group consisted of the central Delta peat soil islands, and the other group included the northern and southern areas having mineral and intermediate organic soil. Data from the 1954-55 study showed that the drainage volume from the central Delta group (study units 18, 20 and 22) contributed about 46.5 percent of the total Delta drainage during June through August and about 32.5 percent from September through May. These percentages were used to proportion the quality data of each island group and provide a single value for each month. These monthly values were then averaged for each calendar month during the five-year period (i.e., all Januarys, all Decembers). These 12 monthly averages were used in the calculations repeatedly for

Table A-1. Equations for Computing Estimates

Compound	Formula	Equation	Percent Carbon
Chloroform	CHCl ₃	$\{C/[C+H+(3 \times Cl)]\} \times 100$	10.05%
Bromodichloromethane	CHBrCl ₂	$\{C/[C+H+Br+(2 \times Cl)]\} \times 100$	7.33%
Dibromochloromethane	CHBr ₂ Cl	$\{C/[C+H+Cl+(2 \times Br)]\} \times 100$	5.76%
Bromoform	CHBr ₃	$\{C/[C+H+(3 \times Br)]\} \times 100$	4.75%

Where: C=12, H=1, Cl=35.45 and Br=79.91

Equation used to estimated theoretical water quality in Delta

$$Dc = [(Sv)(Sc) + (SJRv)(SJRc) + (Mv)(Mc) + (Cv)(Cc)] / (Sv + SJRv + Mv + Cv)$$

Where: Dc = Theoretical THM carbon concentration in Delta water in μ moles/L or mg/L

Sv = Sacramento River volume in ac-ft

Sc = Sacramento River carbon concentration in μ moles/L or mg/L

SJRv = San Joaquin River volume in ac-ft

SJRc = San Joaquin River carbon concentration in μ moles/L or mg/L

Mv = Mokelumne River volume in ac-ft

Mc = Mokelumne River carbon concentration in μ moles/L or mg/L

Cv = Cosumnes River volume in ac-ft

Cc = Cosumnes River carbon concentration in μ moles/L or mg/L

Equations Used to Combine River and Drainage Qualities

River plus drainage:

Crd = $[(Fd)(Cw) + (Fr)(Cr)] / (Fd + Fr)$ using 1954-55 drainage volume

Crd = $[(0.9)(Fd)(Cw) + (Fr)(Cr)] / [(0.9)(Fd) + (Fr)]$ using 90% drainage volume

Crd = $[(1.1)(Fd)(Cw) + (Fr)(Cr)] / [(1.1)(Fd) + (Fr)]$ using 110% drainage volume

Where:

Crd = Carbon concentration of river and drainage mixed in μ g/L or mg/L

Fd = Total Drainage volume in ac-ft

Fr = Total river volume in ac-ft

Cw = Flow weighted carbon concentration of all drains in μ moles/L or mg/L

Cr = Flow weighted carbon concentration of rivers in μ moles/L or mg/L

The following equations were used to proportion the water quality from each Island group.

For June through August estimates:

$$Cw = [(.465)(Cm) + (.535)(Cns)]$$

For September through May estimates:

$$Cw = [(.325)(Cm) + (.675)(Cns)]$$

Where:

Cw = Flow weighted carbon concentration in μ moles/L or mg/L

Cm = Carbon concentration from middle Delta island group in μ moles/L or mg/L

Cns = Carbon concentration from north-south Delta island group in μ moles/L or mg/L

each year. Because of the dearth of quality data for the island drains, this procedure provides data for certain months in some years where no data existed.

Delta Inflow and Outflow Volumes

Riverflow data was obtained from the DWR DAYFLOW database. This database contains information on daily measured river flows to the Delta and measured exports from the Delta. In the DAYFLOW program, precipitation is counted as inflow to the Delta and an estimated volume of water is counted as channel depletion. Channel depletion is an estimate of water use and evaporation in the Delta. To develop a daily Delta outflow volume, all of the exports and channel depletion are summed and subtracted from the sum of the inflows and precipitation.

At the time of data retrieval, the database did not contain flow data after September 1991, so the estimates of drainage effects were not made for the last three months of 1991.

The San Joaquin, Cosumnes, and Mokelumne Rivers have much lower flows than the Sacramento River. In addition, most of the San Joaquin River flow is pumped from the Delta by the Tracy Pumping Plant of the Central Valley Project. To place these flows in perspective the San Joaquin, Cosumnes and Mokelumne river flows averaged 11.3 percent, 0.9 percent, and 0.4 percent, respectively, of the Sacramento River flow during 1987-91.

The San Joaquin River flows were adjusted in the last report to account for the volume of river water that flows directly to the Tracy Pumping Plant. Pumping rates at this plant sometimes exceed the flow of the San Joaquin River, which in effect could limit the volume of river water available for mixing in Delta channels north of Old River. This adjustment decreased the impact that the poorer quality San Joaquin River water may have had on the Delta channels. Because of tidal effects (incoming tides move a large volume of water from the north to the Tracy Pumping Plant), making this adjustment may underestimate the amount of river water available for mixing. In this report Tracy Pumping Plant quality data at the DMC intake is used to estimate the overall quality of the Delta channels; therefore, no adjustment was made on those flows.

Flows in the Cosumnes River and Mokelumne River were used as reported in the DAYFLOW program to flow weight the DOC and TFPC collected from those rivers in 1984.

In the previous 1990 report, the Delta outflow volume was subtracted from the Sacramento River flow measured at Sacramento to estimate the volume of water for mixing in the Delta. The resulting number was then used to flow weight the Sacramento River quality data. For this report period, certain months of heavy precipitation resulted in a Delta outflow that was larger than the Sacramento River flow and the above-mentioned computation resulted in a negative number. Several alternatives using precipitation data and land areas as well as Sacramento River flow at Rio Vista and flow through the Delta Cross Channel gates were examined to derive a reasonable estimate for flow weighting the quality data. None of the alternatives yielded consistently reasonable numbers for all months of the study period. Because the Sacramento River provides almost 90 percent of the total fresh water flow to the Delta, an

adjusted Sacramento River flow was used. This alternative has the advantages of excluding the estimated accretions and decrections for Delta channels and the estimated runoff from precipitation which may only introduce additional error. Also, part of the precipitation that falls on the Delta Islands should enter the mix equations as island drainage. Use of the unadjusted flow of the Sacramento River in the prediction equations results in a lowering of the predicted concentrations.

The highest inflows to the Delta occurred during calendar year 1989. On average, over one million acre-feet of water per month entered the Delta from the Sacramento River. Average monthly flows for calendar year 1991 are the lowest, but 1991 does not include October through December data and, therefore, cannot be equally compared to flows for other years. The lowest inflows to the Delta, for which a complete year of data is available, occurred during calendar year 1990 with average monthly flows of 730,343 acre-feet. Heavy precipitation in the northern watersheds may be the reason for the high Sacramento River flows during 1989. However, precipitation records for Stockton shows calendar year 1987 to be the highest year of precipitation, in that area, with a total of 946,819 acre-feet of water to the Delta. Calendar year 1989 had the second highest rainfall with a total of 670,643 acre-feet. Calendar year 1990 had the least rainfall at 622,882 acre-feet.

Delta Inflow Water Quality

Water quality data for rivers flowing into the Delta were flow weighted to provide an estimate of what the theoretical water quality would be in the Delta channels in the absence of other factors that influence water quality. The rivers used were the Sacramento, San Joaquin, Cosumnes and Mokelumne Rivers. Because the Sacramento River flow constitutes about 90 percent of the total stream inflow to the Delta, its quality is a major controlling factor on Delta channel quality.

Water quality data for the Cosumnes and Mokelumne Rivers were collected between July 1983 and December 1984. Since these two rivers combined represent less than two percent of the total Delta inflow and the quality data has low variability, monthly data collected during the 1984 calendar year was used for each of the five years studied. DOC data was not available for the Cosumnes and Mokelumne Rivers during 1983-84. Water quality data for the Sacramento and San Joaquin Rivers were available for 1987-91.

With the exception of September 1987, all of the annual maximum levels of DOC entering the Delta occurred during months of high precipitation as measured at Stockton. DOC in the Sacramento River was unusually high for that time at 4.90 mg/L. September 1988 and 1989 also had DOC values higher than the annual average for those particular years. No rainfall was recorded at Stockton during September 1987 or 1988, but the record for September 1989 shows 116,541 acre-feet fell in the Delta area. Since no precipitation was recorded north of the Delta during September 1987 and 1988, the reason for the high DOC values is unknown, but may be due to rice field drainage.

The TFPC values were calculated from the TTHMFP measurements. TTHMFP is the

total concentration of chloroform (CHCl_3), bromodichloromethane (CHBrCl_2), dibromochloromethane (CHBr_2Cl), and bromoform (CHBr_3) concentrations. Three of the THM species contain bromine. Because the atomic weight of bromine is more than twice the atomic weight of chlorine, waters containing equal amounts of organic carbon (THM precursor material) but varying amounts of bromine (as bromide ion) will exhibit different TTHMFP concentrations. Therefore, to assess on an equal basis the various sources such as drainages and rivers for organic THM precursors, only the concentrations of organic carbon in the water were compared. To make these comparisons, the carbon percentage for each of the THM species was first calculated. Then the concentrations of each of the four THM compounds were multiplied by their respective percentage of carbon content to obtain the concentrations of carbon. These carbon concentrations were then summed and divided by the atomic weight of carbon to yield the total amount of THM precursor organic carbon in micromoles per liter.

Island Drainage Water Quality

Water quality data was collected from various islands during the study period. The islands were divided into two groups and all of the data in a group that were collected in the same month and year were averaged to give a single value for each group, month and year. One group consists of islands located in Units 18, 20 and 22, as defined in the earlier report. These islands consist of peaty organic soil and are in a high drainage area. The remaining islands consist of intermediate organic and mineral soils and their drainage water is not as high in precursor material as the peat soil drainage. Islands in Units 18, 20 and 22 are Staten, Bouldin, Venice, Empire, King, Terminous, Bacon, Mandeville, McDonald, Mildred and Medford.

DOC and TFPC data for island drainage were derived by first averaging the data, from all of the individual drains in the same island group, collected during a particular month. This produced a set of monthly data for each of the two groups. The two sets of monthly data were then combined into one value for each month by flow weighting the group values by their respective percent flow contribution to the Delta. Equations used to proportion flows are shown in Table 1.

Delta Channel Water Quality

For purposes of comparing the calculated or predicted quality data with actual observed quality data, four Delta stations were selected to characterize monthly channel water quality. Monthly quality data from each of four stations were averaged to provide one value for each month of the study period. The stations selected were Clifton Court Intake, Middle River at Borden Highway, Old River at Rock Slough, and Tracy Pumping Plant.

The monthly station averages for DOC and TFPC showed the greatest amount of organic loading during the months of highest precipitation, normally between December and April.

Methods Used to Estimate Water Quality

To estimate the effect of island drainage, the quality data for each island group and river are proportioned by flow. This yields a flow weighted concentration for each month that estimates the increase in concentration resulting from island drainage. Three different concentrations are calculated, based on 90 percent, 100 percent, and 110 percent of the 1954-55 drainage flows.

Computations were made for the predicted monthly percent increase in DOC and TFPC resulting from island drainage using 90, 100 and 110 percent of the 1954-55 island drainage estimate. These were compared to the observed monthly "Delta" channel carbon. The percent increases shown for 90, 100 and 110 percent of the 1954-55 drainage estimate are calculated by subtracting the monthly inflow carbon values from the estimated increases, dividing the difference by the inflow concentrations, and multiplying the quotient by 100. The observed monthly carbon change is derived by subtracting the monthly inflow carbon concentration from the measured channel carbon concentration, dividing the difference by the inflow value and multiplying the quotient by 100.
